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EVALUATION OF ERTS-1 IMAGERY FOR MAPPING QUATERNARY

DEPOSITS AND LANDFORMS IN THE GREAT PLAINS AND MIDWEST^{1/}

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16. Abstracts <p>Most of the images received in time for study during the reporting period were obtained during the summer growing season; consequently, crops and natural foliage greatly obscure information on geology, soils, and even minor topographic features. In this summer imagery, the "red" MSS band 5 was the most useful for interpreting geologic-terrain units. In the fall images the infrared bands have become more important, as the total infrared response from crops and natural vegetation has decreased.</p> <p>The main landform associations and larger landforms are readily identifiable on the better images and commonly the gross associations of surficial Quaternary deposits also can be differentiated, primarily by information on landforms and soils (obtained by analysis of stream dissection/drainage and stream-divide patterns, land-use patterns, etc.). Maps showing the Quaternary geologic-terrain units that can be differentiated from the ERTS-1 images are being prepared for 20-odd potential study areas (mostly 1° x 2° in size) in Illinois, Iowa, Missouri, Kansas, Nebraska, and South Dakota. Among the more distinct features are the major moraines and outwash channels of the last (Wisconsin) glaciation. Analysis of dissection/drainage patterns from the synoptic imagery is proving useful for detecting anomalies that may be caused by stream diversions and moraines of pre-Wisconsin glaciations, by variable loess deposition, by tectonism, and other factors. Numerous abandoned river valleys have been mapped. Trend-lines of several known pre-Wisconsin moraine systems have been identified in Iowa, Nebraska, and Kansas, and also several similar trend-lines, that may indicate previously unknown moraine systems of middle and possibly early Pleistocene age, have been found in Iowa and Missouri. The area inundated by a major flood in southwestern Iowa also has been delineated from ERTS-1 imagery.</p>			
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- a. Title: Evaluation of ERTS-1 imagery for mapping Quaternary deposits and landforms in the Great Plains and Midwest

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- b. GSFC ID No. of P.I.: IN 404

- c. Problems encountered:

Two processing problems have been corrected: the "reversed" skew of the earliest MSS images, and the Newton rings noted in the 1 November Type I report. One processing problem still remains. The earlier negatives are much too dense to be of any use. They do not yield high-quality enlargements with normal darkroom equipment because of the exceptionally long exposures required. Most of the later negatives are better but still could be improved by a decrease in density. Furthermore, they appear to have significantly less information than the 70mm positive transparencies of the same image. Comparison of enlargements made from these negatives and from the 70mm positive transparencies of the same image reveals much sharper detail on those from the positive transparencies. A few blurred positive images (e.g., 1076-16384) have been received that also are very dense.

The apparent scale-difference/misalignment problem of band 7 versus the other MSS bands, mentioned in the last report, has been identified as a misalignment in the Iowa Geological Survey's I²S Minni-Addcol multispectral viewer.

Apart from these minor problems, the investigation has been hampered seriously in several ways:

(1) Delay in receipt of images. Many of the better images were not received until near the end of the reporting period, and therefore have not yet been fully evaluated. High-quality cloud-free imagery still is lacking for key parts of our study areas. Only 70mm positive transparencies and 70mm negatives (mostly unstable) have been received. No 9"x9" (1:1 million) positive film transparencies have been received, although these are much more advantageous for interpretation.

(2) Atmospheric conditions. These have been unusually poor in this region, due to an exceptionally humid summer and fall. Two-thirds of the images received have considerable cloud cover. In addition, haze and smog conditions, especially in the eastern parts of the region, commonly have degraded the images substantially.

(3) Vegetative cover during the growing season. As was pointed out in the original proposal, the best time of year for imagery of the Great Plains-Midwest for geologic-terrain interpretation, is in the spring, before field crops and woodland/pastureland vegetation obscure details of the soils, geology, and topography. The 4-month-delay in launch of ERTS-1 eliminated the crucial spring imagery. The images taken from July through September have so much vegetative cover that many attempts at geologic-terrain interpretation have been frustrated. Since September the situation has improved, but unfortunately, early snow cover in some parts of the region has partly cancelled this advantage.

(4) Lack of good images permitting stereoscopic viewing. Although the normal 10% endlap of ERTS-1 frames in a given orbital track gives little opportunity for stereoscopic viewing, with repetitive ERTS imagery, the side-lap caused by lateral variations in the tracks affords considerable potential opportunity for such viewing. However, the widespread poor atmospheric conditions to date in the Great Plains-Midwest have reduced the possibility of stereoscopic viewing in our study areas to almost nil.

d. Accomplishments during the reporting period:

Examination procedure

Upon receipt, each 70mm image was given preliminary examination under 10 X magnification and was indexed and evaluated in terms of coverage of the 20-odd potential study areas, cloud cover, contrast, resolution, atmospheric degradation, other defects, and also the geologic-terrain features displayed. Unfortunately, no 9" x 9" (1:1 million scale) positive transparencies were available, except for 3 color-infrared composites that gave partial coverage of several study areas. The 70mm negatives were not usable, as explained under c; consequently, in order to produce a photo base for the interpretations, negative enlargement prints were made from the positive 70mm transparencies at 1:1 million scale and at larger scales where necessary.

Resolution-detection and planimetry measurements

Measurements were made to determine the minimum limits of detectability on four of the best images (1003-16334-5, 1037-16210-5, 1037-16213-5, and 1037-16213-7). Negative enlargements at 1:500,000, 1:375,000, and 1:250,000 scales were used. The smallest detectable, approximately equidimensional objects of moderate to high contrast were about 150-175 feet in diameter. "Diameter" is used because the objects appear only as detectable points on the smaller-scale prints. The smallest features that can be identified as part of a recognizable agricultural pattern are approximately 300 feet on a side for high-contrast and 400 to 500 feet for moderate-contrast features. Rural "section-line" gravel roads are clearly displayed on the red-band images because of their linearity and high contrast. These road right-of-ways, including roadbed, shoulder, ditches, and backslope, range from about 65 to 120 feet, but generally are 74 to 80 feet wide. Several of them, however, gave measured widths of 200 feet or more on the prints, due to the spreading effect associated with bright, highly reflective objects. A known farm pond slightly more than an acre in area (100 x 500 ft) was detectable on a 1:500,000 scale print of infrared band 7.

Prints of these images were compared with base maps of Iowa at scales of 1:1,000,000, 1:500,000 and 1:250,000. Even without precision processing they appear to meet the accuracy of present maps. The images can easily update and improve the accuracy of locating of cultural features on these maps. Preliminary results indicate that level 1 land-use classification, as out-lined by Anderson, et.al. (1972, U.S. Geological Survey Circular 671), can be done readily with the ERTS imagery. A more detailed test of this is planned.

The six-phase interpretation program

In this project, a 6-phase program of interpretation of ERTS-1 data is being used. The progress map (Fig. 1) is keyed to this program and shows the phase of study for each study area.

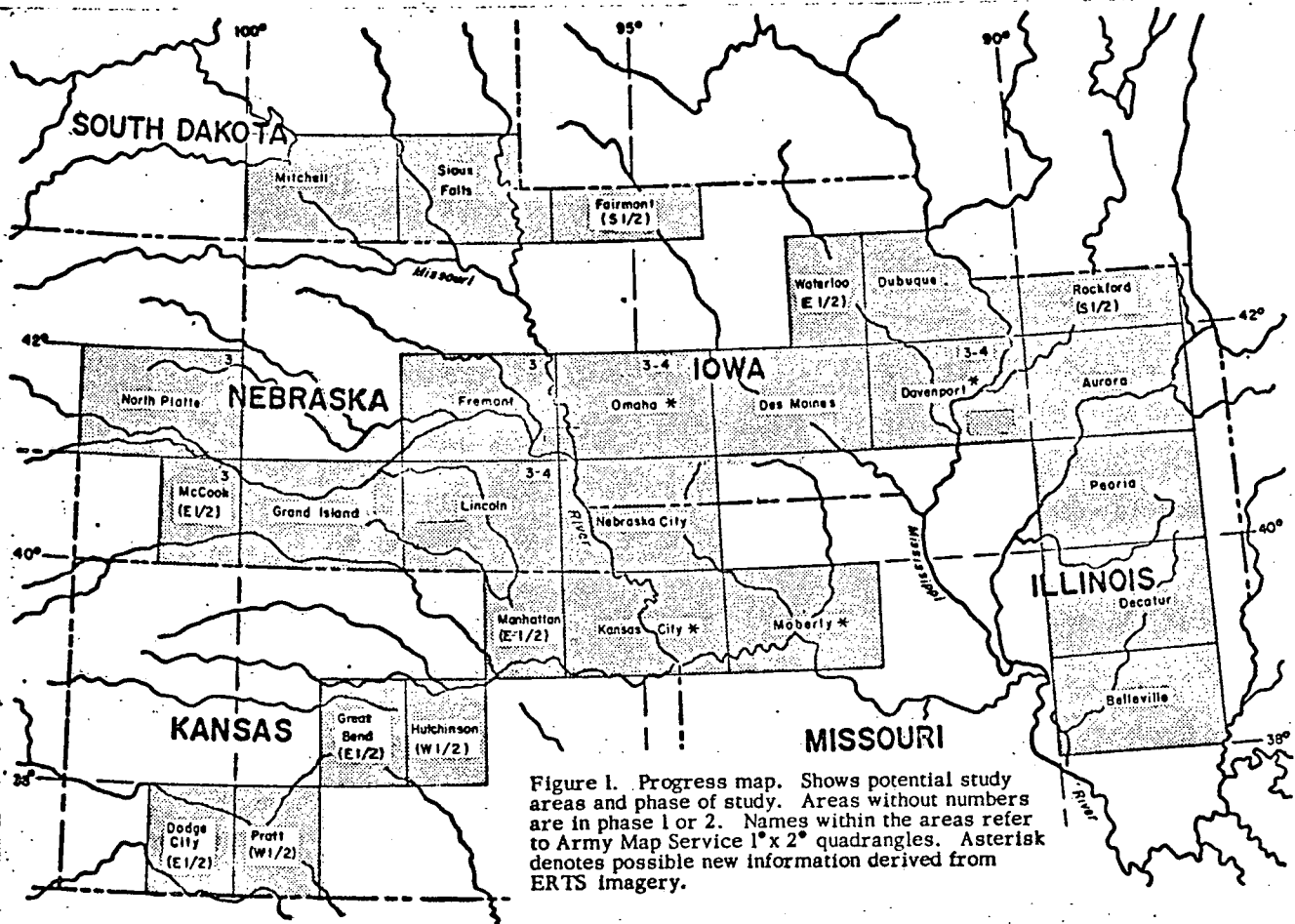


Figure 1. Progress map. Shows potential study areas and phase of study. Areas without numbers are in phase 1 or 2. Names within the areas refer to Army Map Service 1° x 2° quadrangles. Asterisk denotes possible new information derived from ERTS imagery.

Phase 1 consists of preliminary mapping of the pertinent geologic and geomorphic features using only the ERTS-1 imagery.

Phase 2 involves compilation of available published and unpublished ground truth data (geologic, soil, topographic, etc.), preferably on a map of the same scale as that prepared for phase 1, without using ERTS data.

Phase 3 is a comparison of phase 1 and 2 products, with additional photointerpretation, to prepare an "enhanced information" map (at scales ranging from 1:1 million to 1:250,000, as appropriate), noting any differences and anomalies.

Phase 4 consists of additional analysis made from ERTS repetitive coverage of the area, noting added information (at least the differences in information content) gained from time-variant phenomena such as changes in vegetation, soil moisture, snow cover, plowing of croplands, etc.

Phase 5 consists of appropriate field studies to obtain necessary additional ground-truth data, particularly to evaluate anomalies and interesting new features found in phases 3 and 4.

Phase 6 is the delineation of the new information detected from the ERTS imagery.

The interpretive program for a given study area normally progresses in regular sequence through the lower phases, but because the average study area comprises about 7,200 square miles, the investigation later in the program may be in more than one phase in different parts of the study area.

At the end of this reporting period, seven of the study areas were in phase 3 or 4, and the rest were in phase 1 or 2. Examples of the findings from the more advanced studies are given below. It should be understood, however, that the results reported here are preliminary and subject to further testing, including field work (phase 5) where necessary.

General interpretation information

In the summer (July through September) imagery, MSS band 5 ("red") provided the most information about Quaternary deposits and landforms in the Great Plains-Midwest. Nevertheless, the ubiquitous vegetative cover greatly obscured the landforms and geology, and consequently the geologic-terrain interpretations had to be based on land-use patterns as affected by topography. The infrared bands (6 and 7) proved much less useful for mapping geologic-terrain units during this time of year, because the crop cover and natural foliage obscure any unique signals from earth materials. The importance of these bands as discriminators of water is their one virtue that makes them indispensable. In the early fall imagery, information on earth materials from the infrared bands increased as crops dried out and leaves were shed from trees, and thus the infrared reflectance from plants decreased. Spring imagery should be optimal for information on surficial deposits, soils, and landforms.

The larger landforms and association of landforms and surficial deposits are readily identifiable and are being mapped. Among the more distinct features are the more prominent moraines of the last (Wisconsin) glaciation,

and related outwash channels, in Illinois, Iowa, and South Dakota, as illustrated in Table 1. Much less evident are moraines of earlier glaciations. These invariably are severely eroded and buried under variable thicknesses of loess and other sediments. Synoptic analytic study of drainage and stream-divide patterns and of degrees of stream dissection is helpful in detecting anomalies that may signal ancient buried moraines. These studies are greatly facilitated by the comprehensive mega-views provided by the ERTS images. From analysis of drainage- and stream-divide patterns in Nebraska, Kansas, Iowa, and Missouri, the trend-lines of several pre-Wisconsinan moraine systems have been identified that already are moderately well known, mainly from borehole data. Also, several other, similar anomalies that have been found in these states may indicate previously unrecognized pre-Wisconsin moraine systems. Exploration of the anomalous areas in the field will be undertaken as soon as weather conditions permit.

Similar analysis has proved useful for detecting abandoned river valleys. Although some of these are deeply filled by sediment along parts of their courses, others have remained relatively unfilled. Many such valleys or possible buried valleys have been identified in Illinois, Iowa, Nebraska, and Missouri. For example, several ancient valleys of the Mississippi River (resulting from glacial diversion) are evident on images 1036-1615⁴ and 1037-1621³. Several buried bedrock valleys are revealed by their effects on drainage patterns (Fig. 5). Image 1034-1605² shows well the abandoned Cache Valley (Illinois), a spillway of the Ohio River during the last glaciation. The abandoned Todd Valley and Wisconsin-age terraces along the Platte River in Nebraska are shown much better on October 7 image 1076-1633⁴ (bands 5 and 7) than on earlier images (Fig. 2).

Examples follow of our findings in a few of the study areas.

Table 1. Moraines and other glacial features dating from the later part of the last (Wisconsin) glaciation, that have been identified on ERTS-1 MSS images (partial list)

<u>Central Iowa</u>	<u>Frame number, best band(s), date (1972)</u>	
Bemis moraine system (end moraines, ca. 14,000 years old, of the Des Moines glacial lobe; see Fig. 2)	1003-16334-5	26 Jul
	1058-16383-5	19 Sep
	1076-16384-7	7 Oct
<u>Southeastern South Dakota</u>		
Bemis and Altamont moraine systems and stagnation moraines	1023-16434-5	15 Aug
	1041-16433-5,7	2 Sep
	1043-16550-5,7	4 Sep
	1043-16552-5,7	4 Sep
	1060-16491-5,7	21 Sep
	1060-16494-5,7	21 Sep
	1076-16382-7	7 Oct
	1095-16442-7	7 Oct
<u>Northern and central Illinois</u>		
Marengo, Valparaiso, Marseilles, Champagne, Bloomington, and Shelbyville moraine systems	1017-16093-5	13 Aug
	1036-16152-5	28 Aug
	1036-16154-5	28 Aug
	1054-16151-5	15 Sep
	1070-16041-5,7	1 Oct
	1070-16043-5,7	1 Oct
	1070-16050-5,7	1 Oct
	1071-16095-5,7	2 Oct
	1071-16102-5,7	2 Oct
	1071-16104-5,7	2 Oct
	1071-16111-5,7	2 Oct
	1088-16050-5,7	19 Oct
	1088-16052-5,7	19 Oct
	1124-16050-7	24 Nov
	1124-16052-7	24 Nov
<u>South-central Wisconsin</u>		
Johnstown-Milton and Kettle moraine systems, drumlin field and outwash plain.	1017-16093-5	13 Aug
	1036-16152-5	28 Aug
	1054-16151-5	15 Sep
	1070-16041-5,7	1 Oct
	1124-16050-7	24 Nov

Des Moines-Omaha area

The 10,000-sq-mi area from Des Moines to 30 miles west of Omaha and bounded by lats. 41° and 42° has received the most study to date. It includes all of the Omaha 1° x 2° study area, the westernmost part of the Des Moines, and the eastern part of the Fremont study areas. The accompanying map of this area (Fig. 2) has elements of all except phase 5 of analysis. The boundaries between the various geologic-terrain units are from Phase 1; the designations of surficial deposits and their ages are from Phases 2 and 3. Phase 4 (from repetitive ERTS coverage) is beginning to supply additional significant information, with prospects of yielding substantial Phase 6 data (Phase 5 has not yet been possible because of weather conditions).

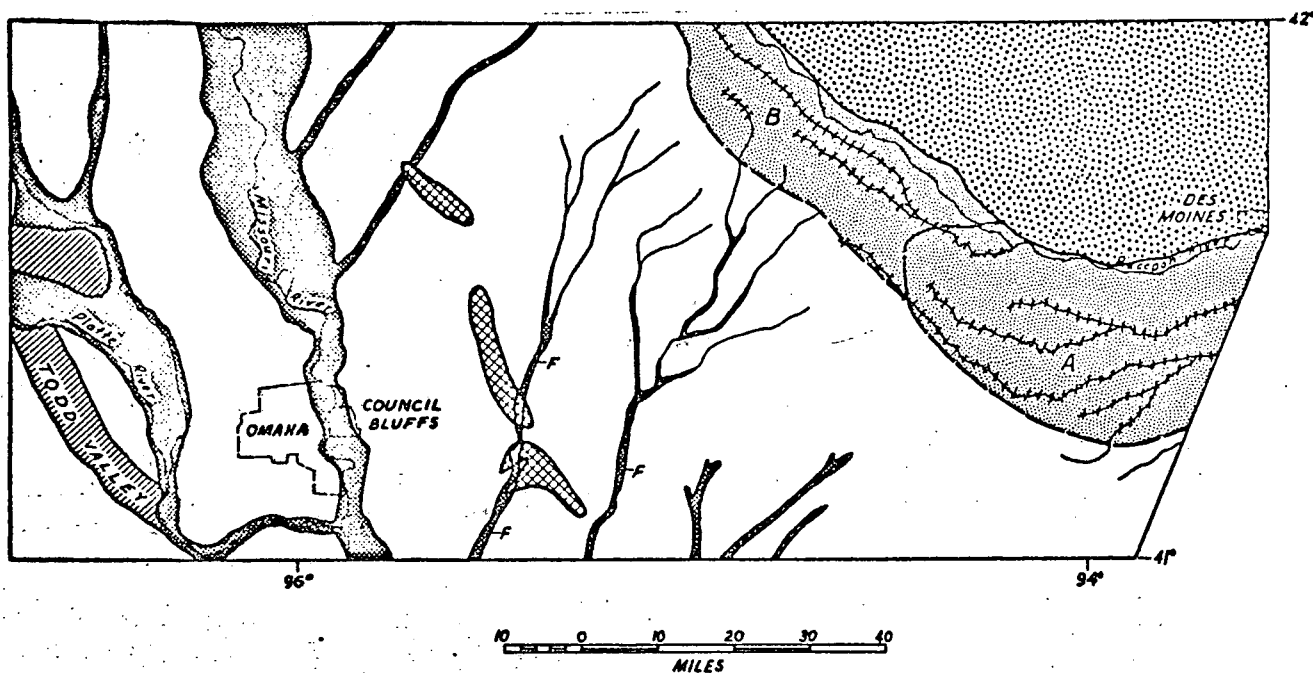
Only a few key findings in this large area will be discussed here. In the eastern third of the area, one of the most obvious features is the boundary between the end moraine (the Bemis moraine, ca. 14,000 years old) of the later part of the last (Wisconsin) glaciation and the dissected loess-mantled plain to the south, that is underlain by thin "Kansan" till over bedrock. As an example of "time of year" differences in information content of the ERTS multispectral images, the outer boundary of the Bemis moraine system is fairly obvious (on the basis of land-use patterns) on band 5 of the July 26 frame 1003-16334 but is indistinct on band 7 of the same frame. In the October 7 frame 1076-16354, however, this boundary is better defined on band 7.

Possible middle or early Pleistocene moraines south of the Des Moines glacial lobe:-- Also in the eastern third of Figure 2 is an interesting area that extends 15 to 24 miles south of the Bemis moraine. This area is "tonally anomalous" (in photo-interpretive terms) in having tone and texture more like the young glaciated terrain within the Des Moines glacial lobe than like the older, moderately dissected "Kansan" till plain of southern Iowa. In addition, this area has not only an arcuate total configuration, but also an arcuate drainage pattern parallel with the Bemis moraine. The tonal anomaly, shown best in images 1003-16334-5 (26 July) and 1076-16384-7 (7 October), is a manifestation of cropland-woodland relationships. In this area the streams are entrenched commonly 150 or more feet through generally less than 50 feet of Pleistocene deposits and into nearly flat-lying Pennsylvanian limestone, shale, and some sandstone, and locally, Cretaceous sandstone and shale. The stream valleys are steep-sided and wooded, whereas the intervening uplands are relatively flat and extensively farmed, thus producing the distinctive tonal-textural pattern. The parallelism of the streams to the outer edge of the Des Moines lobe suggests that their alignment, prior to their entrenchment into the bedrock, may have been controlled by previously unrecognized moraines of an ancient ancestor of the Des Moines lobe, at least Kansan in age, perhaps early Pleistocene.

Supporting this hypothesis is the lack of evidence that the arcuate drainage pattern is controlled by bedrock lithology or structure. The stream valleys cut across several structural trends and across the boundaries of formations having considerable differences in lithology and resistance to erosion. They also cross a buried bedrock valley that runs concordant with the bedrock structure and is assumed to be "preglacial" in age.

Detection of the area inundated by a major flood:-- On September 11 through 13, the East Nishnabotna River, in southwestern Iowa, had a major

Figure 2



PRELIMINARY MAP OF THE OMAHA AND PARTS OF THE DES MOINES AND FREMONT STUDY AREAS

EXPLANATION

Map unit	Landform characteristics	Surficial geologic materials
	Valley lowlands. Flood plains and lower terraces. "F" denotes inundated zones along the East and West Nishnabotna Rivers, detected from ERTS imagery.	Alluvium of late Quaternary (Wisconsinan and Holocene) age.
	Plains, moderately to intricately dissected.	Uplands are mantled with loess of late Quaternary age, over till and other deposits of middle and early Quaternary age.
	Intermediate terrace of the Platte River, and Todd Valley, an abandoned channel of the Platte River.	Alluvium of Wisconsinan age.
	Moraines (Bemis end moraine system) and till plain of the Des Moines glacial lobe.	Till of late Wisconsin (Cary/late Woodfordian) age, locally over older Pleistocene deposits.
	"Tonally anomalous" area with arcuate entrenched drainage paralleling the Bemis moraine system. - Area A is delineated from image 1003-16334-5; area B is a possible extension, from image 1076-16384-7.	Uplands are mantled with rarely more than 20 ft of late Quaternary loess, over till of middle and possibly early Pleistocene age. Total thickness of Quaternary sediments rarely exceeds 50 ft.
	Anomalously dark areas (with low infrared reflectance) on image 1003-16334-7.	Like unit 2. Significance of the infrared anomalies is uncertain. See text.

Streams whose alignment possibly was controlled by moraines of middle or early Pleistocene age.

flood, probably of greater than 100-year-recurrence-interval magnitude. The West Nishnabotna River also flooded, to somewhat lesser degree. The inundated zones along both rivers show clearly as anomalously dark zones on the infrared bands (especially on band 7) of ERTS images taken 6 and 7 days after the flood (frames 1057-16325, 1057-16332, 1058-16383, and 1058-16390). The reduced infrared reflectance is the result of excess soil moisture and plant stress. The inundated zones, as mapped from this imagery, are shown in the south-central part of Figure 2.

Infrared anomalies in southwestern Iowa:-- One early MSS frame, 1003-16334 (26 July), showed in infrared bands 6 and 7 a belt of discontinuous dark areas in southwestern Iowa, 20 to 30 miles east of and parallel with the Missouri River (Fig. 2). These dark areas of reduced infrared reflectance have not appeared on later ERTS images; therefore, they appear to be transient phenomena. Several working hypotheses to explain them have been tested:

(1) The dark areas might be due to specific soil conditions. However, soil maps show no correlation between soil units and the anomalous areas.

(2) The dark areas might coincide with certain topographic features. But topographic maps show no correlation of these areas with topography--the anomalies cut across both divides and valleys.

(3) The anomalies may represent some "signal" related to buried bedrock valleys. Figure 3 shows both the anomalies and the axes of buried valleys in southwestern Iowa. Locally the anomalies coincide with buried valleys, but in other places the correlation does not appear to be very good. Figure 4 shows the thickness of Pleistocene deposits in the area. No apparent correlation is evident here.

(4) The dark anomalies might be caused by wet soil, or even by a combination of wet soil and plant stress, as might result from intense rainstorms, possibly combined with hailstorms. The dark areas are similar in density (on the infrared bands) to the zones inundated by the flood on the Nishnabotna Rivers, mentioned above. On July 25, the day before the image was taken, heavy rains occurred in the area of the dark anomalies (clouds from this storm still are visible in the image). Fig. 5 shows the rainfall for this day. The rain occurred before 6:00 a.m. and the image was taken at 9:33 a.m., local time. As can be seen, nearly all the dark anomalies lie within the area of heaviest rainfall.

The investigators are watching the repetitive ERTS imagery to see if these anomalies reappear, in the hope that further light can be shed on this problem.

The Todd Valley area, Nebraska:-- Todd Valley, shown at the western edge of Figure 2, is an abandoned outwash channel of the ancestral Platte River, dating from the last glaciation. It and a coeval river terrace to the north can be differentiated from younger alluvial lowlands of the Platte and its tributaries better on October 7 image 1076-16334 (bands 5, 6, and 7) than on earlier images. This probably is because of reduction in vegetative cover in the October image.

Lincoln study area, Nebraska

The Lincoln 1° x 2° quadrangle is typical of the transition zone between the unglaciated eastern Great Plains and the Central Plains that were glaciated during the middle and early Pleistocene. The preliminary map of this quadrangle (Fig. 6) differentiates the major types of geologic-terrain areas.

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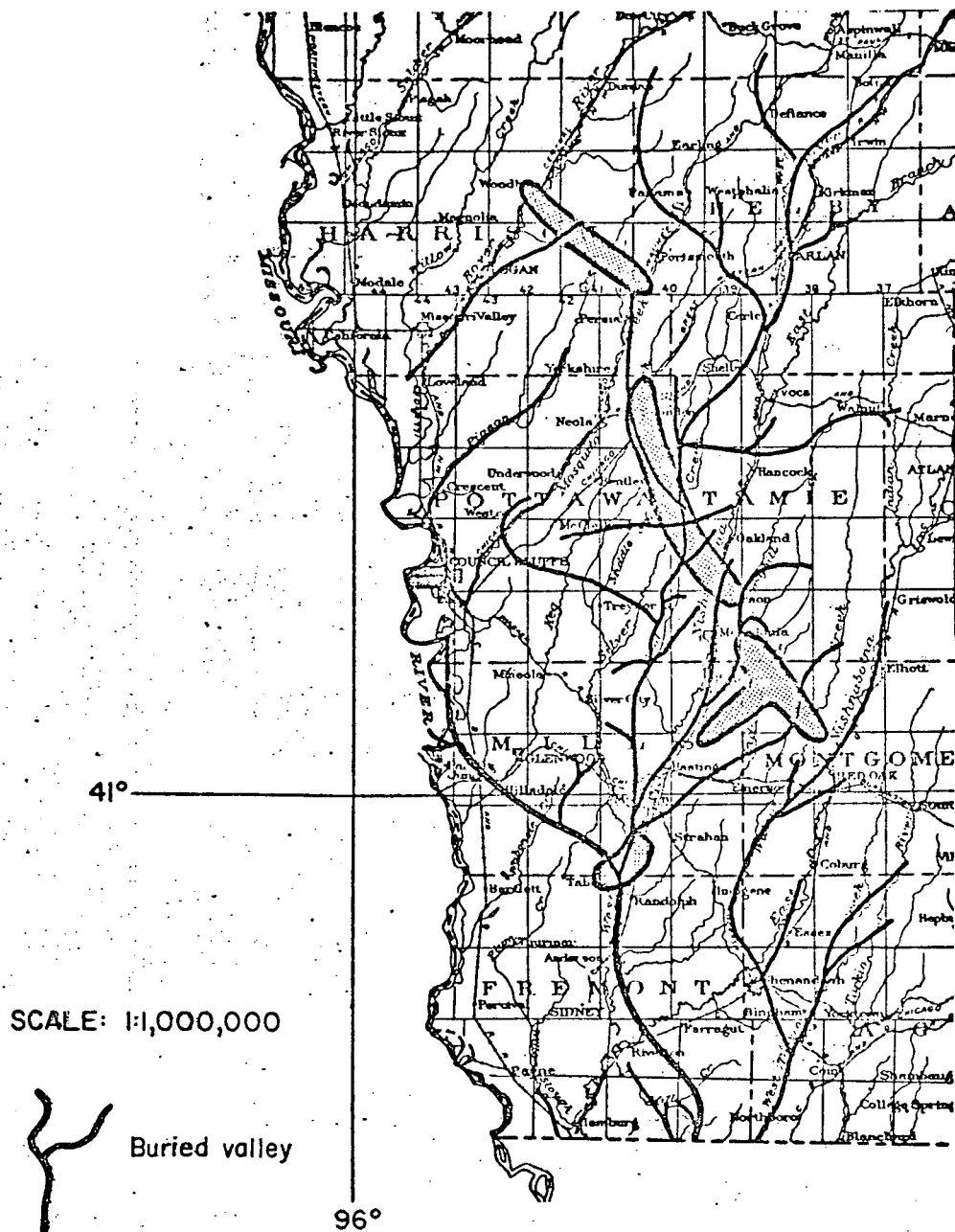


Figure 3. Relationship between infrared anomalies on ERTS-1 image 1003-16334-7 and buried bedrock valleys in southwestern Iowa (after Sendlein and others, 1968).

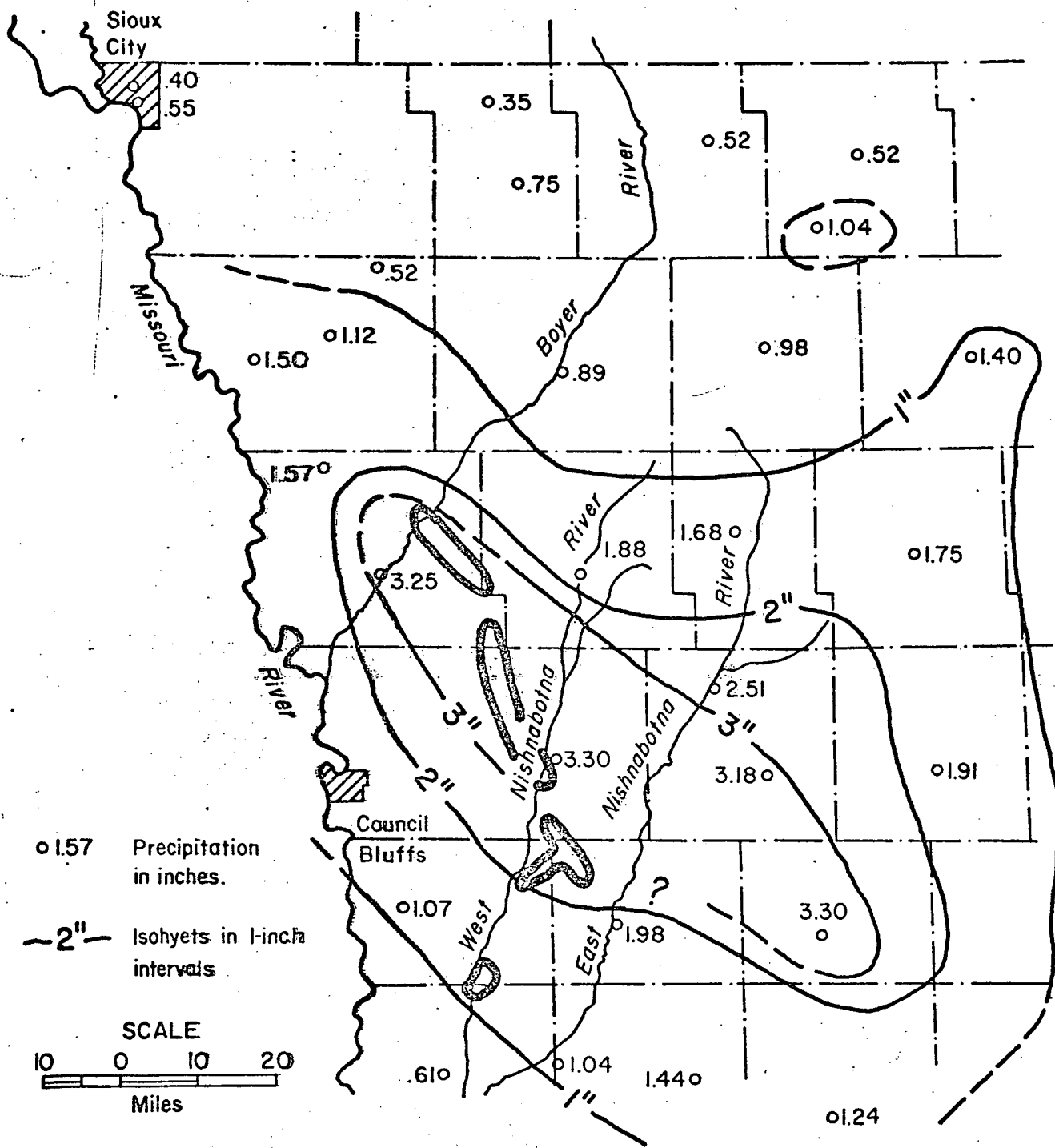
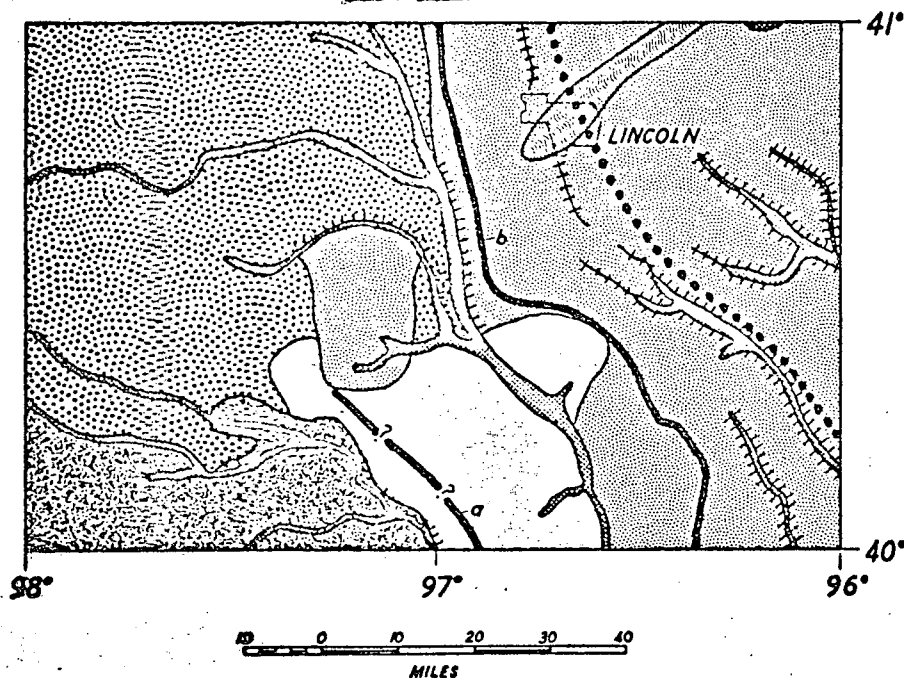


Figure 5. Relationship between infrared anomalies on ERTS-1 image 1003-16334-7 and precipitation during the preceding 24 hours. Rainfall data from National Oceanic and Atmospheric Administration, 1972, Climatological data: Natl. Oceanic Atmospheric Adm., v. 83, no. 7 (July).

Figure 6



PRELIMINARY MAP OF THE LINCOLN, NEBRASKA, STUDY AREA

EXPLANATION

Compiled from ERTS-1 images 1022-16384-5; 1095-16451-5, 7; 1076-16391-5, 7

Map unit	Landform characteristics	Surficial geologic materials
	Plains with widely spaced streams and wide, nearly level interstream uplands. Main streams are entrenched generally less than 100 ft.	Uplands have thick loess mantle of late Quaternary age, overlying middle and early Pleistocene alluvium and loess, and till locally in eastern portion.
	Moderately dissected plains. Moderately wide to narrow, relatively level interstream uplands; stream valleys moderately spaced. Main streams are entrenched 100 to about 200 ft.	
	Moderately dissected plains like above.	Uplands have thin to thick loess mantle of late Quaternary age, over middle and early Pleistocene till, alluvium, and other deposits.
	Intricately dissected plains with closely spaced valleys and narrow interstream uplands. Main streams are entrenched 100 to rarely more than 200 ft.	
	Valley lowlands distinguishable on the ERTS images: flood plains and lower alluvial terraces, hachured where alignment possibly was controlled by moraines of middle or early Pleistocene age.	Alluvium and local loess of late Quaternary (Wisconsinan and Holocene) age.
	Ancient (middle Pleistocene) valley	

Streams without lowlands distinguishable on ERTS images, whose alignment possibly was controlled by moraines of middle or early Pleistocene age.

Drainage divide controlled by known morainic system of middle Pleistocene ("Kansan") age. a = moraine of the Nickerson Till; n = moraine of the Cedar Bluffs Till.

Trend-line of drainage anomaly, possibly due to moraine system of middle or early Pleistocene age.

The important features identified from the ERTS images are (1) a buried valley, trending northeast from Lincoln, that is indicated by an aberrant stream pattern, and (2) palimpsests of three moraine systems of Kansan and perhaps older age. These have been substantiated by surface and drill-hole data collected by members of the Nebraska Geological Survey.

North Platte and eastern McCook study areas

The combination map of two study areas (Fig. 7), the North Platte and eastern 1/2 of the McCook quadrangles, is representative of both the Sand Hills and the High Plains of western Nebraska. Although coverage by satisfactory ERTS images still is incomplete and limited mostly to images obtained during the growing season, vegetative cover in this semiarid region is less of an impediment than in the more humid areas to the east. Analysis of both land-use patterns and stream-dissection patterns has permitted mapping the major geologic-terrain units. Furthermore, on the best available frame (1043-16555) showing the Sand Hills portion, the configurations of the larger dunes and inter-dune depressions can be distinguished clearly. The infrared band also affords a synoptic register of the water-level status of the myriads of ponds in this area, and thus it gives assistance in keeping an up-to-date inventory of ground-water conditions. (Hydrologists lately have become concerned about possible depletion of the ground-water reservoir by overpumping in some parts of the Sand Hills.)

Davenport study area

Possible moraine-controlled drainage divides of Illinoian age are shown on the map of the Davenport quadrangle in Iowa and Illinois (Figure 8). Previously mapped boundaries of glacial deposits and terrain units, such as the physiographic boundaries between the Kansan and "Iowan" regions, are not, in many cases, clearly delineated on the imagery. ERTS frame 1037-16213 (29 August) was compared with 1969 A.S.C.S. airphotomosaics of Scott County, Iowa, photographed in late spring at a scale of 1 inch to the mile. The Cleona Channel¹ (Figure 8) is evident on the ERTS imagery only where it influences major streams such as the Cedar and Wapsipinicon Rivers. The broad sag between these two streams appears on the spring mosaic because of different soil properties and soil-moisture conditions, neither of which can be detected on the summer ERTS imagery. Also the paha² lineations that are prominent on the mosaic do not appear at all on the ERTS imagery. Although these features have distinct soil properties, they do not topographically affect agricultural patterns enough to be recognizable on the image at that time of year.

South-central Wisconsin

In south-central Wisconsin just beyond the principal study areas, interpretations were made because of a great variety of glacial features

¹ An abandoned channel of the Mississippi River formed as a result of diversion by the Lake Michigan glacial lobe in Illinoian time.

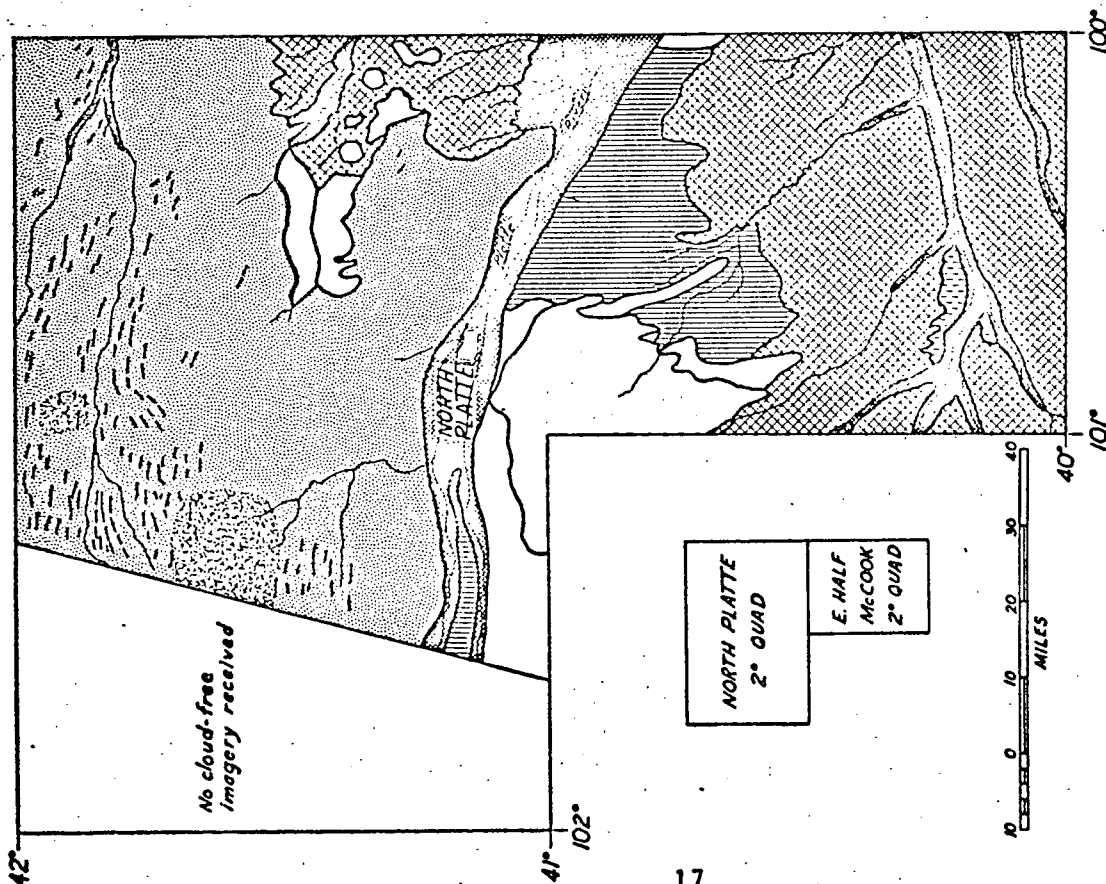
² A term used in the Midwest for a loess-covered linear ridge.

Figure 7

PRELIMINARY MAP OF THE NORTH PLATTE
AND EASTERN MCCOOK, NEBRASKA, STUDY AREAS

EXPLANATION

Map unit	Landform characteristics	Surficial geologic materials
	Valley lowlands--flood plains and lower alluvial terraces	Alluvium of late Quaternary (Wisconsinan and Holocene) age
	Higher, most extensive and continuous sand dunes. Local relief commonly 100 to 250 ft. Transverse and longitudinal dunes alternate with narrow interdune lowlands that have ponds and marshes locally; very few streams. Heavy dashed lines indicate trends of the larger elongate dunes. Heavy stipple shows areas with many active sand blowouts.	Eolian sand, 50 to more than 250 ft thick, over middle Pleistocene alluvium, loess, and other deposits.
	Lower sand dunes and sand plains with isolated dunes; local relief generally less than 75 ft; very few streams.	Eolian sand, 5 to rarely more than 75 ft thick, over middle Pleistocene alluvium, loess, and other deposits.
	Plains, nearly level, with local relief generally less than 50 ft, rarely 100 ft; few, widely spaced streams.	Loess and local eolian sand over middle Pleistocene alluvium and loess.
	Moderately dissected plains (local relief generally less than 200 ft), moderately wide to narrow, relatively level interstream uplands; stream valleys moderately spaced.	Uplands have thick loess mantle of late Quaternary age over middle Pleistocene alluvium and loess, and in the SW half of the McCook E1/2 quadrangle, over bedrock (mainly Ogallala Formation).
	Moderately dissected plain (local relief generally less than 100 ft).	Uplands have loess mantle of late Quaternary age over possibly either middle Pleistocene alluvium of bedrock.
	Highly dissected plains (local relief commonly about 200 ft), with closely spaced valleys and narrow interstream valleys.	Uplands have thin loess mantle of late Quaternary age over middle Pleistocene alluvium and loess.



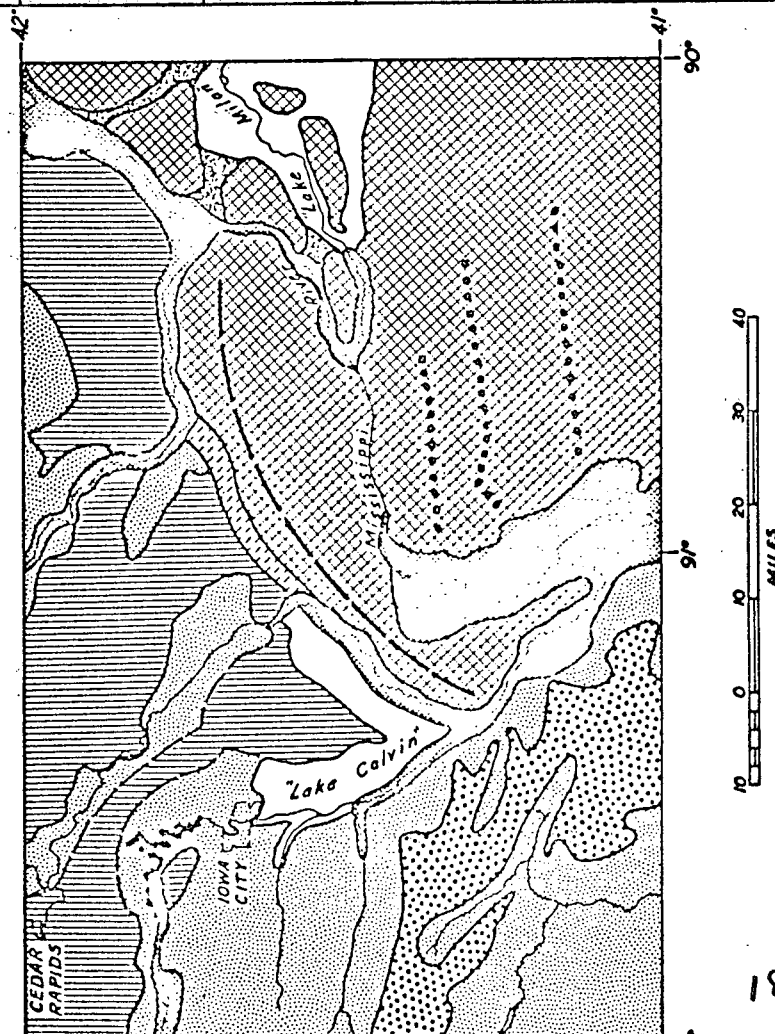
EXPLANATION

Map unit	Landform characteristics	Surficial geologic materials
	Valley lowlands, Flood plains and lower river terraces.	Alluvium of late Quaternary (Holocene and late Wisconsinan) age.
	Lowlands slightly higher than above, Abandoned channels of the Mississippi River.	Alluvium of late Wisconsinan age.
	Lowlands mostly slightly higher than unit 1.	Alluvium of late Wisconsinan and Holocene age over deposits of proglacial lakes (Lake Milan, of late Wisconsinan age east of the Mississippi; and Lake Calvin, of Illinoian(?) age, west of this river).
	Moderately dissected plain; local relief commonly 75 to 100 ft; rarely more than 150 ft; moderately to closely spaced streams.	Uplands are mantled by 10 to more than 25 ft of loess of late Quaternary age, over till of Illinoian age (all ground moraine except just east of the Cleona Channel).
	"Cleona Channel," an ancient channel of the Mississippi River, formed when this river was diverted by one or more advances of the Lake Michigan glacial lobe during the Illinoian glaciation.	Loess mantle of late Quaternary age over alluvium of Illinoian age.
	Plains with widely spaced streams and broad, nearly level interstream uplands. Main streams generally are entrenched less than 50 ft.	Uplands have variable loess cover, commonly 10 to 15 ft or more thick, of late Quaternary age, over till of middle Pleistocene (Kansan) age. Total thickness of Quaternary deposits generally is less than 60 ft.
	Moderately dissected plains; stream valleys moderately to closely spaced; interstream uplands narrow to moderately wide (wider ones are nearly level); local relief commonly 50 to 100 ft, generally less than 150 ft.	
	Intricately dissected plains with closely spaced valleys and narrow interstream uplands. Main streams are entrenched commonly 100 and rarely more than 150 ft.	

.....
 Anomalous valley trends, suggesting control by buried stream channels of Illinoian or earlier age.

—
 Possible end-moraine system of Illinoian age, buried by loess of late Quaternary age; suggested by drainage divide/drainage pattern analysis.

Figure 8



discernible even on the late summer (August and September) images. The drumlin lineations mapped are not individual drumlins, but rather trends revealed in land-use patterns that are affected by the drumlins. Similarly, trends of the Johnstown terminal moraine system are shown by land-use and stream patterns and by trends of lakes and poorly drained areas. The wetlands show best on band 7 of the September (1054) imagery, and additive viewing of bands 5 and 7 provided good discrimination of the poorly drained areas. On this basis the larger areas of interpreted poorly drained soils and wetlands were mapped.

Plans for the next reporting period

The P.I. and Co-P.I. will continue examination of ERTS-1 imagery and preparation of phase 1, 2, 3, and 4 maps of the various study areas. Phase 5 (field study, with emphasis on possibly significant anomalies detected from the ERTS images) will be begun in February, probably to investigate suspected buried moraines of middle and early Pleistocene age in northwestern Missouri, in company with Dr. William Allen (who is in charge of Quaternary geologic investigations for the Missouri Geological Survey).

e. Significant scientific results and their practical applications:

This project is testing the applicability of ERTS-1 imagery for synoptic identification and mapping of geologic and geomorphic units ("geologic-terrain" units) in the Midwest-Great Plains, including end moraines of the last glaciation, terrace sequences along main rivers, and ancient (middle and early Pleistocene) glacial moraines and filled valleys that have been buried beneath younger glacial drift, loess, or eolian sand. Unfortunately, most of the images received in time for study during the reporting period were obtained during the summer growing season; consequently, crops and natural foliage greatly obscure the information on geology, soils, and even minor topographic features. In this summer imagery, the "red" MSS band 5 was the most useful for interpreting geologic-terrain units. In the fall images, the infrared bands have become more important, as the total infrared response from crops and natural vegetation has decreased.

The main landform associations and larger landforms are readily identifiable on the better images and commonly the gross associations of surficial Quaternary deposits also can be differentiated, primarily by information on landforms and soils (obtained by analysis of stream dissection/drainage and stream-divide patterns, land-use patterns, etc.). Maps showing the Quaternary geologic-terrain units that can be differentiated from the ERTS-1 images are being prepared for 20-odd potential study areas (mostly 1° x 2° in size) in Illinois, Iowa, Missouri, Kansas, Nebraska, and South Dakota.

Among the more distinct features are the major moraines and outwash channels of the last (Wisconsin) glaciation, for example the Shelbyville and Bloomington moraine systems in Illinois and the Bemis and Altamont moraine systems in Iowa and South Dakota. Analysis of dissection/drainage patterns from the synoptic imagery is proving useful for detecting anomalies that may be caused by stream diversions and moraines of pre-Wisconsin glaciations, by variable loess deposition, by tectonism, and other factors. Numerous abandoned river valleys have been mapped. Trend-lines of several known pre-Wisconsin

moraine systems have been identified in Iowa, Nebraska, and Kansas, and also several similar trend-lines, that may indicate previously unknown moraine systems of middle and possibly early Pleistocene age, have been found in Iowa and Missouri.

Some study areas, already well mapped, provide checks on the reliability of mapping from the images. For other study areas, previously mapped only partly or not at all, our maps will be the first comprehensive, synoptic ones, and should be useful for regional land-use planning and ground-water, engineering-geology, and other environmental applications.

The area inundated by a major flood in southwestern Iowa also has been delineated from ERTS-1 imagery.

f. Published articles, etc. released during the reporting period. None.

g. Recommendations. None.

h. Changes in Standing Order Forms. None.

i. ERTS Image Descriptor Forms. See following attachment.

j. Data Request Forms submitted to GSFC/NDFF during reporting period, by date: None.

e, continued. Category designation: 3 I, 10 B.

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Clouds	Rural Area	Flood- plain	
1019 - 16215	X			
1019 - 16220	X			
1019 - 16224		X		Lake, Meander
1019 - 16225		X		Lake, Meander
1036 - 16152	X	X	X	City, Drumlins, Bedrock
1036 - 16154		X	X	City, Lake, River
1036 - 16161		X	X	City, River
1036 - 16171	X			
1039 - 16332	X			
1039 - 16334	X			
1039 - 16341	X			
1041 - 16433	X	X		Lakes
1041 - 16435	X			Lakes
1043 - 16550		X		Lakes, River, Meander
1043 - 16552	X	X		Dunes, River, Lakes
1043 - 16555	X	X	X	Dunes
1044 - 17020	X			
1045 - 17063	X			
1045 - 17065	X			Lake
1052 - 16052		X	X	Dendritic Drainage Forest
1054 - 16151		X	X	City, Drumlins, Bedrock
1054 - 16154	X	X	X	City, Lake, River
1054 - 16160	X			
1055 - 16210	X	X	X	
1055 - 16212	X	X	X	
1055 - 16215		X	X	Meander
1055 - 16221	X	X	X	Meander
1055 - 16224	X	X		Lake, City

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Clouds	Rural Area	Flood- plain	
1056 - 16264	X	X		Lake
1056 - 16271	X	X		Lake
1056 - 16273	X	X		
1056 - 16282	X	X		City, Lake, Dendritic Drainage
1057 - 16323	X			Lake
1057 - 16325		X		City, Lake
1057 - 16332		X	X	Meander
1057 - 16334	X	X	X	
1057 - 16341	X			Cirrus
1058 - 16383	X	X	X	City, Meander
1058 - 16390		X	X	City
1058 - 16392		X	X	Lake
1058 - 16395	X	X	X	Dendritic drainage
1060 - 16491		X		Lakes
1060 - 16494		X	X	Dunes, Lake, River
1060 - 16500		X	X	Dunes
1060 - 16503		X	X	Lake, Irrigation
1060 - 16505	X			
1060 - 16512	X			
1061 - 16552		X	X	Dunes, Lakes, River
1061 - 16555	X	X	X	Dunes, Irrigation
1061 - 16561		X	X	Meander, Irrigation
1070 - 16041	X			EEO Urban Area, Airfield, Lake Agriculture, Jetty
1070 - 16043	X	X	X	Lake, River
1070 - 16050		X	X	Lake, River
1070 - 16052		X	X	Lake, Meander
1071 - 16093	X			
1071 - 16095	X			EEO Urban Area. Airfield, Lake, Jetty

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Clouds	Rural Area	Flood- plain	
1071 - 16102		X	X	City
1071 - 16104		X	X	Meander, River, Dendritic
1073 - 16212	X	X	X	
1073 - 16215	X	X	X	Lake
1073 - 16221		X	X	Meander
1073 - 16224		X		Lake, City, Dendritic Drainage
1076 - 16382	X	X		Lake
1076 - 16384		X	X	Meander, City Parallel Drainage
1076 - 16391		X	X	City, Meander
1076 - 16393		X	X	Lake
1076 - 16400	X			Lake
1077 - 16434	X			
1077 - 16440	X			
1078 - 16492	X			Lakes
1088 - 16043	X			
1088 - 16050		X	X	Dendritic Drainage
1088 - 16052	X	X		Dendritic Drainage River
1089 - 16095	X			
1089 - 16102	X			
1089 - 16104	X			
1089 - 16113	X			
1094 - 16395	X			
1094 - 16402	X			
1095 - 16440	X			Lakes
1095 - 16442		X	X	Lakes, River
1095 - 16445		X	X	Meander
1095 - 16451		X	X	Lake
1095 - 16454		X		Lake, Dendritic Drainage

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Clouds	Rural Area	Flood- plain	
1095 - 16460	X			
1096 - 16503	X			
1096 - 1651-	X	X	X	Lake
1097 - 16552	X	X	X	River, Lakes
1105 - 15595		X	X	Meander River
1105 - 16002		X	X	Meander River
1106 - 16054	X			
1108 - 16171	X			
1108 - 16173	X	X	X	Lakes
1111 - 16340	X			
1111 - 16345	X			
1114 - 16500	X			Lakes
1114 - 16502	X			

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Flood	Moraine	Outwash	
	Drainage		Plain	
1057-16325,7	x			
1057-16332,7	x			
1058-16383,7	x			
1058-16390,7	x			
1003-16334		x	x	
1036-16152		x	x	
1036-16154		x		
1041-16433		x		
1054-16151		x	x	
1060-16491		x		
1070-16043		x		
1076-16384		x		

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Clouds	Rural Area	Flood- plain	
1095 - 16460	X			
1096 - 16503	X			
1096 - 1651-	X	X	X	Lake
1097 - 16552	X	X	X	River, Lakes
1105 - 15595		X	X	Meander River
1105 - 16002		X	X	Meander River
1106 - 16054	X			
1108 - 16171	X			
1108 - 16173	X	X	X	Lakes
1111 - 16340	X			
1111 - 16345	X			
1114 - 16500	X			Lakes
1114 - 16502	X			

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Flood	Moraine	Outwash	
	Drainage		Plain	
1057-16325,7	x			
1057-16332,7	x			
1058-16383,7	x			
1058-16390,7	x			
1003-16334		x	x	
1036-16152		x	x	
1036-16154		x		
1041-16433		x		
1054-16151		x	x	
1060-16491		x		
1070-16043		x		
1076-16384		x		

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